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Added value of three-dimensional transesophageal echocardiography in assessment of prosthetic mitral paravalvular leaks.

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ORIGINAL ARTICLE

Added Value of Three-dimensional Transesophageal Echocardiography in Assessment of Prosthetic Mitral Paravalvular Leaks

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Abstract

Background: **A well-known, crucial consequence of prosthetic valves that have been surgically or percutaneously inserted is a prosthetic paravalvular leak. It usually occurs as a result of insufficient sealing of the prosthetic ring to the native heart tissue, either immediately after surgery or much later as a consequence of infective endocarditis.**

Aim and objectives: **The main aim of this study was to compare 3D TEE with 2d TEE regarding Initial diagnosis and localization of PVLs, assessment of size, shape and severity of PVLs and assessment of the feasibility for percutaneous closure.**

Subjects and methods: **This cross-sectional study was carried out on 30 patients diagnosed with prosthetic mitral paravalvular leaks. The duration of the study ranged from 6 to 12 months.**

Result: **There was a significant increase (overestimation) in size measured by 2D compared to size by 3D ($P = 0.015$) while there was no significant difference between 2D & 3D regarding VC ($P > 0.05$). Regarding the site of the leak there was a significant association between sites detected by 2D and 3D ($P < 0.001$). Regarding ERO, it was significantly positively correlated with size by 2D ($r = 0.660$, $P < 0.001$) and VC by 2D ($r = 0.789$, $P < 0.001$). There was significant association between severity detected by 2D and 3D ($P < 0.001$) with good agreement (kappa = 0.71).**

Conclusion: **In the assessment of the morphology of mitral PVL, real-time three-dimensional transesophageal echocardiography is superior to two-dimensional TEE because it provides a detailed description of the number, location, size, and shape of the leak, which is essential for planning and guiding potential corrective techniques.**

Keywords: Prosthetic paravalvular leak (PVL), 3D TEE: three-dimensional transesophageal echocardiography

1. Introduction

A well-known, crucial consequence of prosthetic valves that have been surgically or percutaneously inserted is prosthetic paravalvular leak. It usually occurs as a result of insufficient sealing of the prosthetic ring to the native heart tissue, either immediately after surgery or much later as a consequence of infective endocarditis. The two main manifestations of prosthetic paravalvular leaks are heart failure and/or hemolysis, and they can range in severity from mildly asymptomatic to severely symptomatic.[1]

PVLs are more frequently found in mitral prostheses, where they are present in 7%−17% of patients.[2] The preferred course of treatment for clinically significant PVLs has traditionally been surgery. However, in a carefully chosen group of patients, percutaneous transcatheter closure treatment has shown to be a beneficial option.[3]

The initial diagnosis, evaluation of the severity, and localization of the PVL all depend heavily on echocardiography. Additionally, it is very important when

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determining if percutaneous closure is feasible and when providing intra-procedural guidance. Transesophageal echocardiography (TEE) provides an advantage over transthoracic echocardiography (TTE) given the intricacy of many PVLs in that it is not impacted by the mitral prosthesis' acoustic shadow, which often obscures the regurgitation jets and makes TTE assessment challenging.[4]

The main aim of our study is to compare 3D TEE with 2d TEE regarding next items: initial diagnosis and localization of PVLs, assessment of size, shape and severity of PVLs and evaluation of the percutaneous closure's possibility.

2. Patients and methods

Our study was prospective study on 30 patients with prosthetic mitral paravalvular leak. The study was performed at National heart institute at the period from December 2021 to February 2023.

Prior to patient allocation, patient informed written agreement and local ethical committee approval were acquired.

2.1. Inclusion criteria

All patient with prosthetic mitral paravalvular leak. Including Patient with other valve replacement or infective endocarditis, congenital heart disease.

2.2. Exclusion criteria

Decompensated heart failure, active respiratory tract infection and high bleeding tendency.

2.3. Two-dimensional transesophageal echocardiography (2D -TEE)

TEE was done using matrix array X7-2t transducer on Philips EPIQ7C ultrasound machine that is suitable for both multiplane 2D and real-time 3D imaging. Mitral prosthesis screening was done in several planes sweeping the mitral prosthesis from 0° to 180° for detection of any dehiscent areas. The locations and number of the paravalvular leaks were determined using Doppler color flow. The angle at which the jet is first detected until the angle of its disappearance was noted to estimate the extent of the leak (size). The severity of PVL was evaluated semi quantitively using visual estimation and measuring vena contracta width and regurgitation jet area. Severe mitral PVL was defined as vena contracta width of >6 mm[5] (Fig. 1).

2.4. Real-time 3D transesophageal echocardiography (RT-3D TEE)

3D TEE imaging was achieved during the same procedure with 2D TEE. Standard 2D images were used to determine the best plane for 3D imaging the

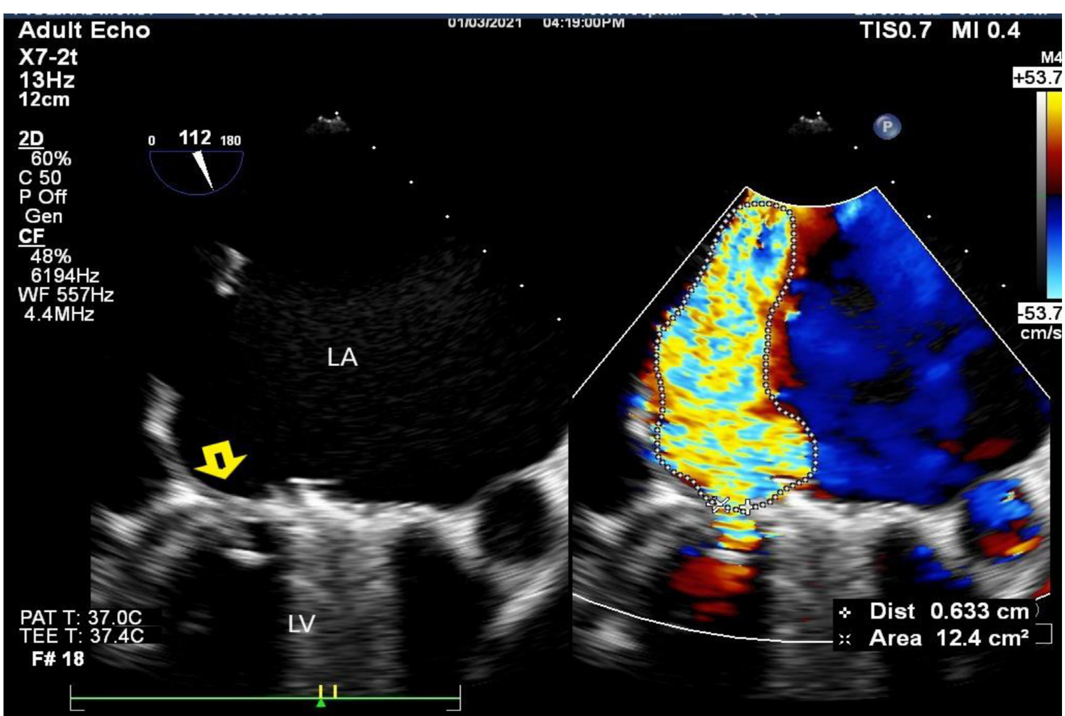

Fig. 1. Panels A and B, paravalvular leak PVL (yellow arrow) by color TEE. LA = left atrium; LV = left ventricle.

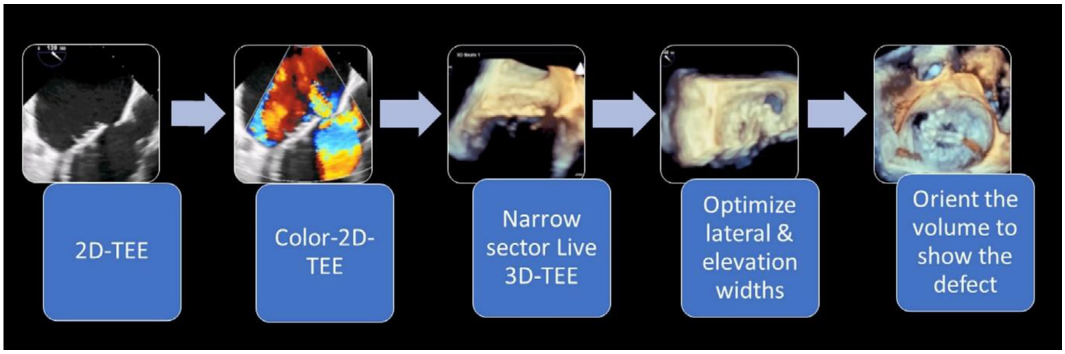

Fig. 2. Flowchart for the proposed imaging protocol.

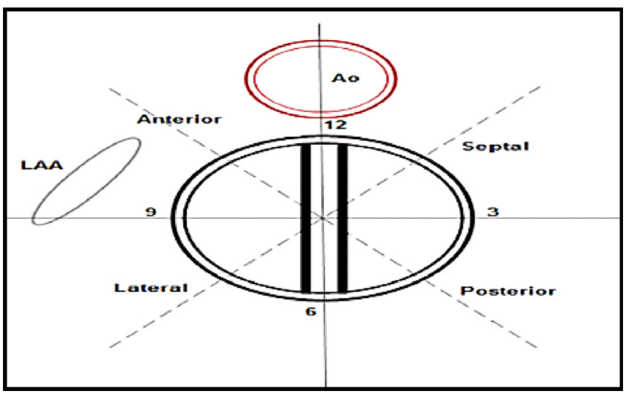

Fig. 3. Schematic figure for surgical view with the location of the leak. Anterior leak (on the annulus between 9 and 12 o'clock), posterior leak (between 3 and 6 o'clock), septal leak (between 12 and 3 o'clock) and lateral leak (between 6 and 9 o'clock).[6] Ao, aorta; LAA, left atrial appendage.

mitral valve prosthesis. Then before narrow-angled acquisition, the gain settings were optimized. Subsequently, 3D zoom approach was used to focus on the mitral valve prosthesis and the paravalvular defect from atrial view. Finally, color full-volume acquisition was done after limiting the probe motion and asking the patient to hold breath for few seconds to avoid the stitch artefact. ECG gating was used during the latter mode to merge at least 4 narrower pyramidal scans over at least 4 cardiac cycles. Images were assessed and cropped offline for optimal visualization of the PVL and assessment of the area, width and length of the defect was done using QLAB multi-planar reconstruction tool. Paravalvular leaks (PVLs) were described in terms of their shape, size, number and localization (Fig. 2).

2.5. Number of PVLs

Based on full-volume 3D color Doppler results and real-time 3D image, the number of PVLs (single or multiple) was documented.

2.6. Localization

The corresponding hour was used to describe location of the leak. As seen from the left atrium,

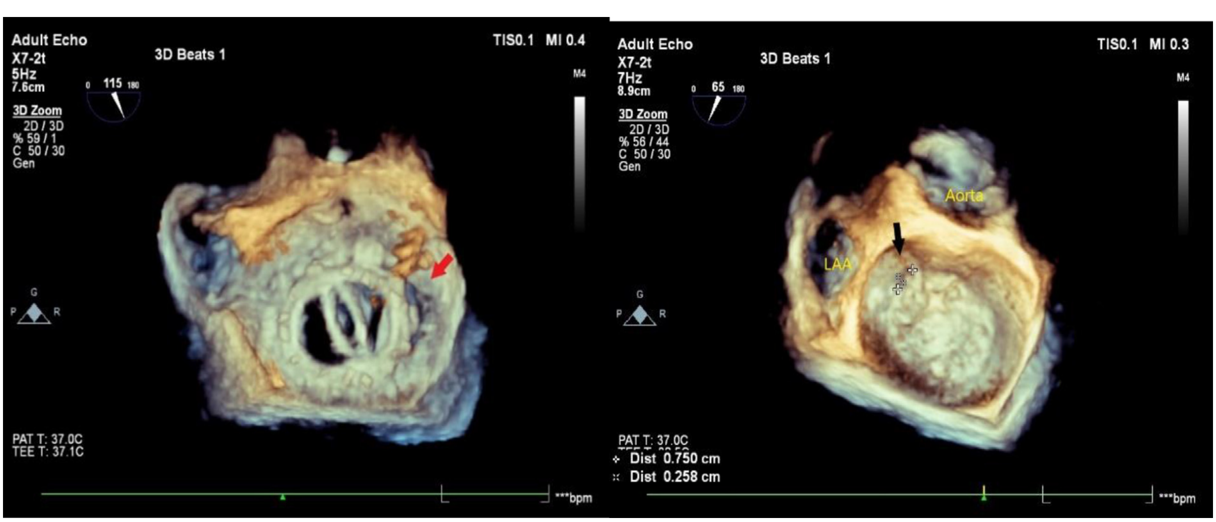

Fig. 4. 3D-zoomed images showing site of leak, Mitral valve prosthesis in a surgical view, with a PVL (red & black arrow).

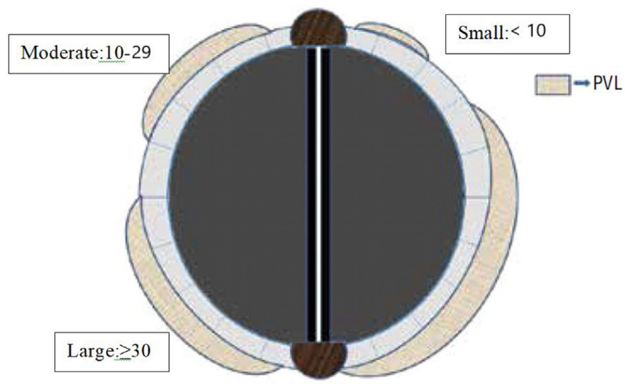

Fig. 5. The leaks were categorized based on their size from circumferential annular ring (small, moderate and large).[7]

twelve o'clock was assigned as the mid-point of the anterior annulus and six o'clock as the mid-point of the posterior annulus. The left atrial appendage is at nine o'clock, while the interatrial septum is at three o'clock as shown in (Figs. 3 and 4).

2.7. Size

On 3D TEE images the dimension of the paravalvular defect were measured. As shown in (Fig. 5), leak was classified as 'small' if it less than 10% of the annular ring's circumference, 'moderate' if it between 10% to 29% of the ring, and 'large' if it more than 29% of the ring. Dehiscence was described when a significant paravalvular defect exceeded 40% of the annular ring's circumference.[6] (Figs. 6 and 7).

2.8. Shape

The leaks were described as 'crescent', 'round', 'oval' or 'irregular'.[7]

2.9. Effective regurgitation orifice

Measurement of multi-planar reformatting (MPR) was shown to be more accurate than direct planimetry on the 3D image because the earlier is less impacted by gain settings. The severity of PVL was shown to be more closely related to assessment of the effective regurgitant orifice (ERO) using color 3D[5] as shown in (Fig. 8).

2.10. Data collection, statistical analysis & presentation

Microsoft Excel software was used to code, enter, and analyze historical data, basic clinical examinations, laboratory investigations, and outcome

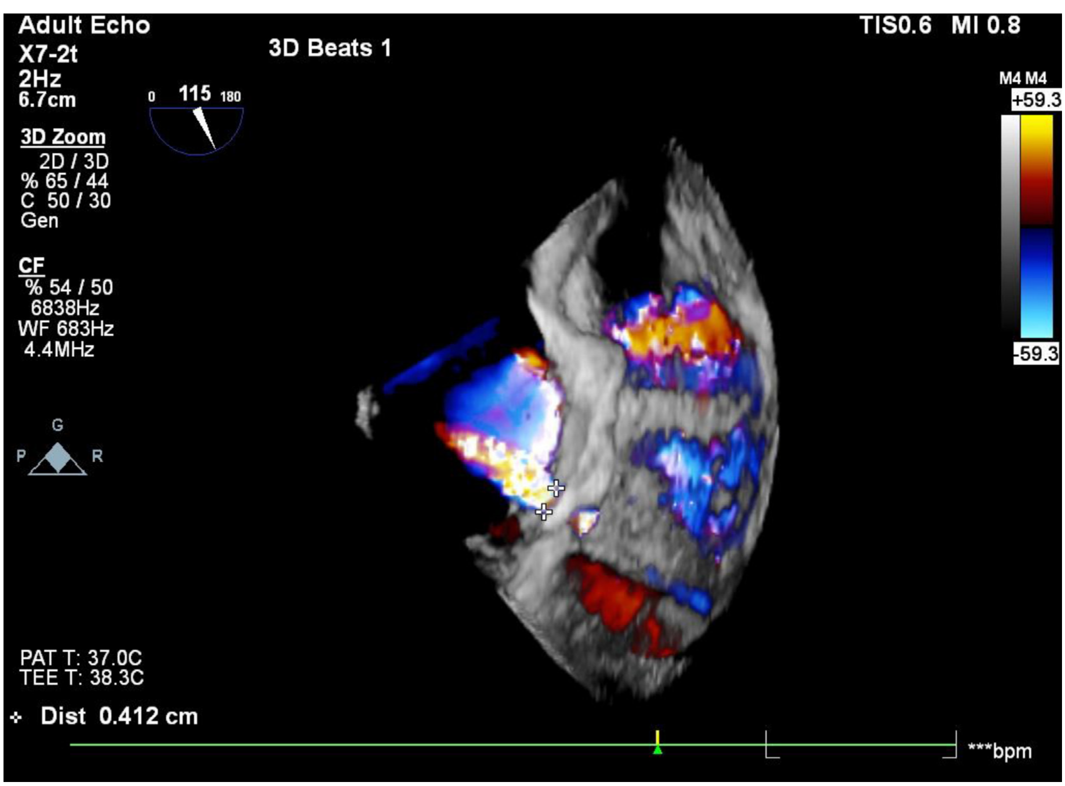

Fig. 6. Show measuring vena contracta of mitral PVL using color 3D.

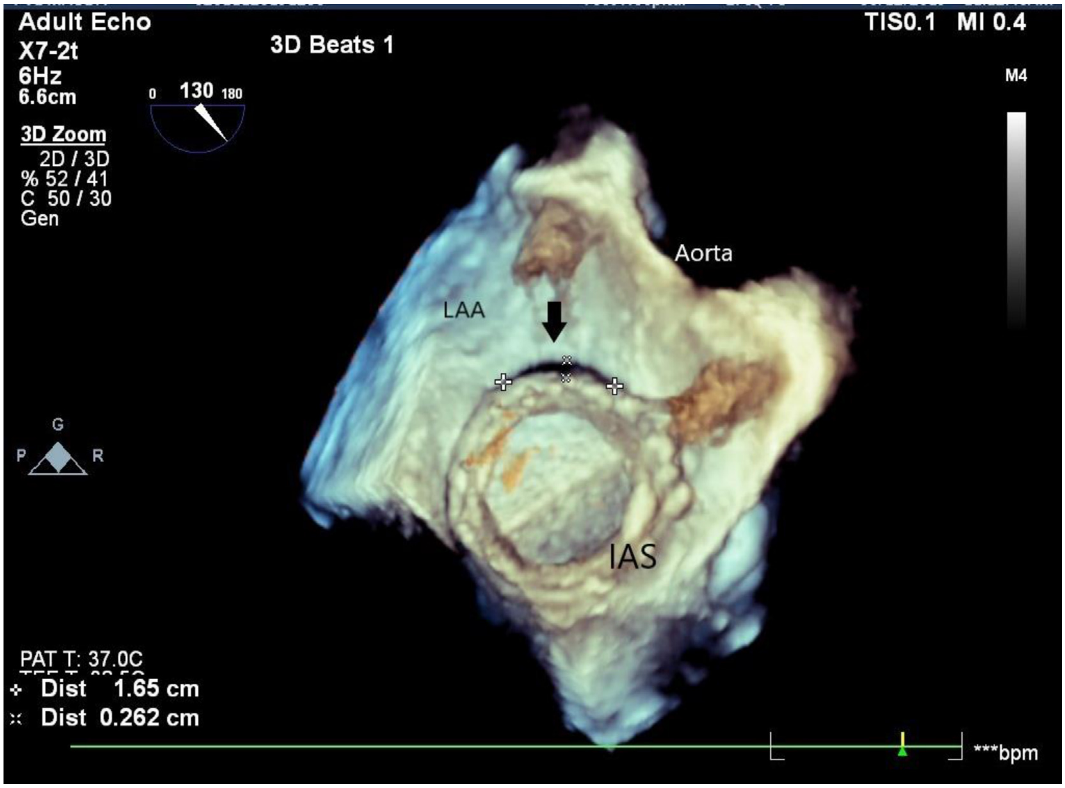

Fig. 7. 3D-zoomed surgical view of a mitral valve prosthesis with a leak (black arrow) from 10 to 12 o'clock with a slit-like shape.

measurements. The data was then imported and analyzed utilizing the SPSS version 20.0 application, which stands for Statistical Package for the Social Sciences. The following tests were utilized to determine if differences were significant based on the kind of data; qualitative data are represented as numbers and percentages, while quantitative data continue to be grouped by means ± SD. Chi square test (X2) compares and connects qualitative variables. Paired *t*-test for differences between quantitative paired groups; Pearson's correlation for correlation. *P* value was set at <0.001 for results that were significantly significant and <0.05 for results that were significant.

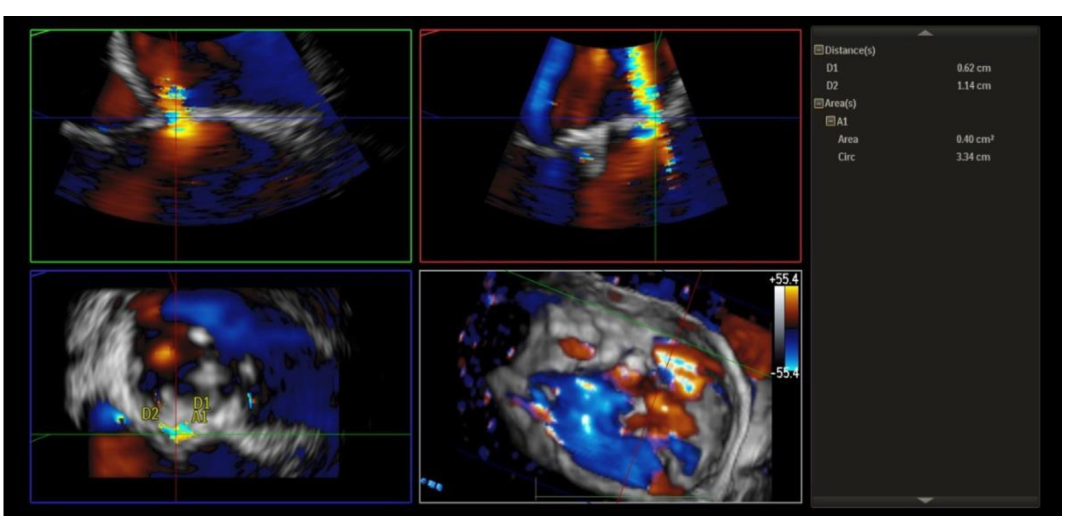

Fig. 8. Planimetry of effective regurgitant orifice (ERO) area of mitral PVL using multi-planar reformatting (MPR).

Table 1. Illustrates 2D transesophageal echo parameters among the studied cases.

	PHT
PHT	
Mean ± SD	79.36 ± 20.1
Median (Range)	75.0 (54–130)
MVA	
Mean ± SD	2.90 ± 0.64
Median (Range)	2.9 (1.7–4.0)
MAX_PG	
Mean ± SD	11.56 ± 2.35
Median (Range)	11.0 (8–18)
Mean PG	
Mean ± SD	5.1 ± 1.58
Median (Range)	5.0 (3–10)
RJA	
Mean ± SD	7.25 ± 2.96
Median (Range)	7.05 (3–2)

MVA, mitral valve area; PG, pressure gradient; PHT, pressure half time; RJA, regurgitation jet area.

Table 2. Illustrates 3D Transesophageal echo parameters among the studied cases.

	ERO
Mean ± SD	0.30 ± 0.09
Median (Range)	0.30 (0.12–0.45)
	N (%)
Shape_3D	
Crescent	5 (16.7)
Irregular	1 (3.3)
Oval	13 (43.3)
Round	11 (36.7)
Total	30 (100.0)

ERO, Effective Regurgitation Orifice.

3. Results

Tables 1–6.

4. Discussion

In the study in our hands, regarding association between sites detected by 2D and 3D. septal site was the most common site found by both 2D and 3D. there was significant association between sites detected by 2D and 3D ($P < 0.001$). As regard our group study by 2D TEE there was 8 patients show anterior paravalvular leak but when estimated by 3D TEE was found that 6 patients from these 8 patients show anterior leak and 2 patients show lateral leak. Also, there was 8 patients show lateral leak by 2D TEE but by 3D TEE was found that 6 patients from these 8 patients was lateral and 2 patients was anterior. Also, 4 patients show posterior leak by 2D TEE but by 3D TEE only one of them had posterior leak and 2 lateral and one septal leak. Also, 10 patients show septal leak by 2D TEE but with 3D TEE 9 of them had septal leak and one had posterior leak.

Our results were supported by study of Arribas-Jimenez et al.,[8] as they reported that by 2D TEE, the site of the 26 leaks was lateral in 8 (31%), septal in 10 (38%), posterior in 2 (8%) and anterior in 4 patients (15%). In 2 patient (8%), the PVL's position could not be determined. They had extremely eccentric jets and their position was posteriorly. By RT-3DTEE, the site of the 37 leaks was lateral in 11 (30%), septal in 13 (35%), posterior in 5 (13%) and anterior in 8 patients (22%) ($P > 0.05$). They were detected by 2D TEE as 10 lateral (77%), 2 posterior (40%), 8 septal (73%) and 4 anterior (50%) leaks. In 10 patients (38%), where the site could not be determined by 2D TEE or when more than one leak was discovered by RT-3DTEE, there was no proper association between 2D and 3D TEE.

Whereas, according to some authors Krishnaswamy et al.[9]; Lee et al.,[10] Vecera et al.,[11] The posteromedial and anterolateral portions of the mitral valve annulus are where mitral PVLs are most common.

Table 4. Illustrate size and VC distribution between 2D and 3D.

	2D	3D	Paired t	*P*
Size	22.78 ± 7.63%	20.50 ± 6.13%	2.57	0.015*
VC	5.19 ± 1.69	5.17 ± 0.16	0.23	0.81

Table 5. Showed correlation between 3D and other parameters.

act	Size_3D	VC_3D	ERO
2D Size			
r	0.842**	0.734**	0.660**
P	0.000	0.000	0.000
2D VC			
r	0.722**	0.962**	0.789**
P	0.000	0.000	0.000

Table 3. Showed association between sites detected by 2D and 3D.

	Site 3D				X^2	*P*
	Anterior	Lateral	Posterior	Septal		
Site 2D						
Anterior *N* (%)	6 (75.0%)	2 (20.0%)	0 (0.0%)	0 (0.0%)	37.63	0.00**
Lateral *N* (%)	2 (25.0%)	6 (60.0%)	0 (0.0%)	0 (0.0%)		
Posterior *N* (%)	0 (0.0%)	2 (20.0%)	1 (50.0%)	1 (10.0%)		
Septal *N* (%)	0 (0.0%)	0 (0.0%)	1 (50.0%)	9 (90.0%)		
Total *N* (%)	8 (100.0%)	10 (100.0%)	2 (100.0%)	10 (100.0%)		

Table 6. Showed association between severity detected by 2D and 3D.

	3D			X^2	*P*	Kappa agreement
	Mild	Moderate	Severe			
2D						
Mild *N* (%)	3 (75.0%)	1 (6.2%)	0 (0.0%)	28.21	0.00**	0.71
Moderate *N* (%)	1 (25.0%)	14 (87.5%)	3 (30.0%)			
Severe 1 *N* (%)	0 (0.0%)	1 (6.2%)	7 (70.0%)			
Total *N* (%)	4 (100.0%)	16 (100.0%)	10 (100.0%)			

Our results showed that the mean size measured by 2D and 3D was 22.78 ± 7.63% and 20.50 ± 6.13% respectively from swing ring of Mitral valve. The mean vena contracta (VC) measured by 2D and 3D was 5.19 ± 1.69 mm and 5.17 ± 0.16 mm respectively. There was significant increase (over estimation) in size measured by 2D compared to size by 3D ($P = 0.015$) while there was no significant difference between 2D & 3D regarding VC ($P > 0.05$). There was significant positive correlation between size by 3D with size by 2D ($r = 0.842$, $P < 0.001$) and VC by 2D ($r = 0.722$, $P < 0.001$). In addition, VC by 3D was significantly positive correlated with size by 2D ($r = 0.734$, $P < 0.001$) and VC by 2D ($r = 0.962$, $P < 0.001$). Regarding ERO, it was significantly positive correlated with size by 2D ($r = 0.660$, $P < 0.001$) and VC by 2D ($r = 0.789$, $P < 0.001$). There was significant association between severity detected by 2D and 3D ($P < 0.001$) with good agreement (kappa = 0.71).

Our results were supported by the study of Singh et al.,[12] revealed that 13 patients with prosthetic paravalvular regurgitation who were previously planned for surgical repair did intraoperative real-time 2D TEE and live/real-time 3D TEE. In all patients, 3D TEE was capable to give more description according to the size and location of the leak as compared to 2D TEE. When compared to 2D TEE, 3D TEE produce a more definite information about location and size of the leak that closely matched with surgical results. The preliminary findings show that 3D TEE is more effective than 2D TEE in assessing paravalvular leak. A more precise estimation of the extent of the leakage is provided by 3D TEE in addition to an accurate evaluation of its precise location. This data could be helpful to surgeons who might struggle to locate and assessment the amount of Para prosthetic leakage while the heart is anesthetized during surgery.

While, in the study of Arribas-Jimenez et al.,[8] According to RT-3DTEE, the median PVL size was 7 mm long and 4 mm wide. And by 2D TEE and RT-3DTEE, the median vena contracta of the deficiency was found to be 5 mm and 4 mm, respectively ($P > 0.05$). The mean ERO area determined by RT-3DTEE was 0.36 cm^2 (range 0.15–2.10); mild paravalvular leak was represented by 0.18 cm^2, moderate paravalvular leak by 0.29 cm^2, and severe paravalvular leak by 0.78 cm^2.

Furthermore, Mahmoud-Elsayed[13] revealed that when it comes to evaluating PVLs, 3D TEE has been demonstrated to provide greater diagnostic accuracy than 2D TEE, particularly in patients with multiple PVLs. This is because the PVL's location, size, shape, and guidance for transcatheter percutaneous closure have been better defined.

4.1. Limitations of the study

The study was restricted to single-center with small number of patients. Preoperative, intraoperative and postoperative data of the enrolled patients were not available.

4.2. Conclusion

In the assessment of the morphology of mitral PVL, real-time 3D TEE is superior to 2D TEE because it provides a detailed description of the number, size, location, and shape of the leak, which is needed for planning and guiding potential corrective techniques.

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Conflicts of interest

Authors declare that there is no conflict of interest, no financial issues to be declared.

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